Literature Review – Methods for accounting for the Carbon Intensity of Biomethane

Prepared for

Bioenergy Association of New Zealand

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2 Executive Summary

This research was used to develop the first New Zealand specific carbon accounting framework for RNG. The research references the leading clean fuel standards and RNG REC schemes within Canada, USA and Europe. Each international scheme has its own associated methodologies as detailed in the research and explained in this document.

Every International RNG CI method and model defines the RNG Carbon Intensity (CI) slightly differently though all follow a life cycle assessment (LCA) approach. The key areas of variability within the CI models are the system boundaries, assumptions, predefined default data, prescribed emission factors and timeframes. A RNG CI is producer, scenario and model dependent; the fuel property changes over time depending on the supply chain and process to create the fuel.

Some international methodologies cover avoided emissions also which is primarily used for policy development and carbon credit schemes. Though excluded from the scope of the NZ RNG CI methodology which aligns with ISO 14067 Carbon Footprint of Products, it is still touched on within this research.

This research leveraged the key principles of many of the international methodologies augments them with the NZ Bioenergy Association specific requirements for the three system processes to develop RNG from organic waste. In particular the research looked at the below system processes as they relate to biomethane production and GHG quantification.

1. Landfill gas recovery
2. Municipal wastewater treatment
3. Organic waste diversion to AD Plant

The research does a brief look at international REC scheme structure but does not complete a GAP analysis between the current situation in NZ and international best practice.

3 Purpose

The purpose of this literature review is to inform the development of a Biomethane/ Renewable Natural Gas (RNG) carbon intensity (CI) methodology for New Zealand. The most recent international RNG greenhouse gas (GHG) methodologies, RNG certification schemes, Low Carbon Fuel Standards and Biogas Association and sector body publications were assessed. The list of references is available in the Appendix A.

4 Intended Use/Users

The intended users of the biomethane carbon intensity methodology are mainly biomethane / RNG producers and the users of the RNG. The intended use is to define a consistent, comprehensive and verifiable approach for biomethane product carbon accounting, to satisfy the requirements of international renewable energy certificates (RECs) schemes.

Some international RNG models and methodologies are designed to estimate the climate change mitigation from Biofuel programmes across a country. These methods and models are not as applicable to the deliverable and intent of this research.

This research focuses on assessing the carbon intensity of a biomethane/ RNG Product created from renewable organic waste streams.

The intended use and users within the bioenergy sector of NZ was agreed with key sector stakeholders. This information defined the quality requirements of the GHG methodology and prioritised areas of focus for the research and development of the carbon intensity methodology.

Stakeholder Type	*Standards / References*	*GHG Accounting Typology*
Certifier / Verifier	14064-1 Organisation GHG; 14067 Product Standard; GHG protocol organisational inventory ISO 14064-3 GHG assurance	Organisational emissions / Product Carbon Footprint
Project Developers / RNG Producers	14064-2 Project GHG accounting; 14067 Product Standard; International REC schemes; International Clean Fuel Standards	Biomethane carbon intensity
RNG Certificate	European Energy Certificate System (EECS); Green Gas Certification Scheme (GGCS) UK; International REC (I-REC)	Biomethane carbon intensity
Clean / Low Carbon Fuels standards	Canada's Clean Fuel Regulations (CFR); U.S. Renewable Fuel Standard (RFS)	Biomethane carbon intensity
Consumers / Organisation GHG	14064-1 Organisation GHG; 14067 Product Standard; PAS 2050;	Organisational emissions / Product Carbon Footprint

5 References/ Research

During the research phase the most recent international GHG methodologies were assessed and incorporates into this biomethane carbon intensity methodology for NZ.

Core questions have been asked when developing the research paper that will feed into the above methodology development. The answers to the below questions can be found throughout this document.

1. What are the various system boundaries (ie. cradle to gate & cradle to grave) and how are they to be used by producers and consumers of biomethane?

2. How are carbon emissions allocated across the main product (biomethane) and the co-products (CO_2 + Digestate)?
3. How are the various GHG gasses accounted for? Biogenic carbon, N_2O, CH_4 vs. non-biogenic.?
4. Is embodied carbon from the AD plant construction included?
5. What is the recommended functional unit for biomethane carbon intensity? GJ/ kWh?
6. What are the typical GHG sources, inputs and outputs (i.e. activity data) for the carbon intensity calculation?
7. What are the activity data (input/ outputs) quality requirements (primary or secondary)?
8. What is the formula for carbon intensity for biomethane for the 3 processes? WWTP, LFG, AD plant.
9. What are the record keeping requirements pertaining to assurance / verification requirements? What are the other verification requirements to be determined?
10. What is the frequency of LCA reporting and verification required by biomethane producers?
11. What are the temporal boundary requirements for activity data and emission factors?
12. How is the onsite electricity and heat generation addressed?
13. How is backloading addressed in feedstock transportation?
14. What are the fundamental requirements of a biomethane REC? What is the international landscape of these requirements and what are the key gaps/ remaining uncertainties?
15. How are RECs used in the RNG user GHG inventory?
16. How should mass balancing used to ensure the production system is accurately represented, emissions are appropriately allocated across biogas and other byproducts, and the feedstock can be verified to meet sustainability requirements?
17. What is the requirement / data quality for Emissions Factors and Calculation methodologies? (e.g supplier specific vs. hybrid).
18. What default values and Emissions Factors should be dictated to ensure comparability across calculations?
19. How is electricity emissions treated in the production process of biomethane? Can Scope 2 RECs be used? How should onsite electricity be accounted for?
20. What is uncertain or still to be determined in the leading methodologies that will require NZ Bioenergy association decisions?

6 Fundamental Questions

6.1 What is the definition of carbon intensity (CI)?

The carbon intensity (CI) of a RNG can be defined as the carbon footprint / unit of energy of the fuel based on the lifecycle stages and specific inputs and outputs of the production. See below figure from the Canadian Clean Fuel Regulations (CFR) scheme showing the typical lifecycle stages of a RNG CI.

Each international renewable fuels programme and REC scheme has its own calculation methodology guidance and models to support biomethane producers and the sector. The carbon intensity GHG Calculation methodologies are based on a Lifecycle Assessment (LCA) approach. International Product Carbon Footprint Standard ISO 14067-1 defines LCA in a comprehensive - yet general - manner to cover all products.

Every International RNG CI method and model defines the renewable fuels CI slightly differently though all follow an LCA approach. The key areas of variability within the CI models are the system boundaries, assumptions, predefined default data, prescribed emission factors and timeframes. A RNG CI is producer, scenario and model dependent; this fuel property changes over time depending on the supply chain and process to create the fuel.

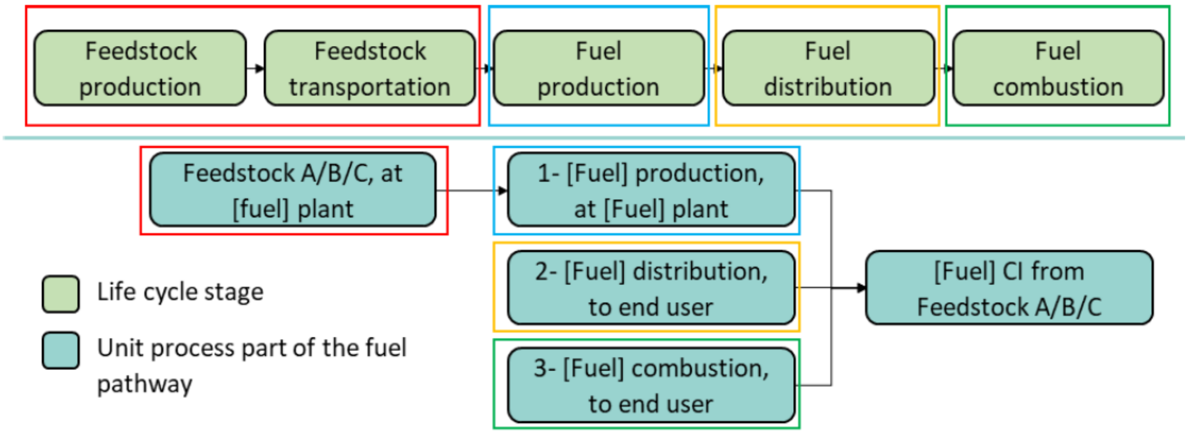

Figure 1 - Scheme lifecycle stages for CI calculation, from Canadian Clean Fuel Regulations (CFR), figure [13]

6.2 What is the common functional unit for RNG?

ISO 14064-1 defines a functional unit as the reference unit used in the quantified performance of a product system. This facilitates determination and comparison of reference flows for the systems being studied.

Based on international research, the biomethane / RNG fuel functional unit is MJ or kWh of fuel energy based on the Higher Heating Value (HHV). The system boundary of the RNG lifecycle assessment defines the carbon intensity per functional unit in carbon equivalents (CO_2e) either in gCO_2e or $kgCO_2e$. The carbon intensity per functional unit is typically CO_2e/ Energy Content of fuel, commonly gCO_2e/MJ, or $kgCO_2e$/GJ.

Carbon intensity is typically based on the annual amount of biogas generated by a process, per the megajoule (MJ) of fuel, or per kWh/MWh of electricity depending on the biogas' end use application.[1] Sometimes, such as within the CFR scheme, the functional unit is per kg of fuel at the production gate.

The functional unit for RNG producers is typically all "material"/ significant cradle to gate LCA activities to produce pipeline specification biomethane / RNG. For producers the cradle to gate

[1] American Biogas Association; Carbon Accounting Methodology for Biogas, 2024

activities include feedstock extraction, feedstock transportation, and the RNG production to pipeline specification. See more on system boundaries below.

The functional unit for RNG users is typically all “material”/ significant Cradle to Grave LCA activities to produce and use pipeline specification biomethane / RNG including pipeline transmission and distribution losses.

6.3 What is the system boundary for biomethane carbon Intensity?

System boundary for reporting CI is dependent on which guideline or standard is being followed. Cradle to gate is aligned with the requirements of the NZ Bravetrace REC, Canadian CFR, EU REDcert, World Biogas Association and US REC schemes. The Canadian Clean Fuel Regulations scheme require reporting of both boundaries, EU RED Cert and American Biogas Association require cradle to grave.

The LCA gate is at the pipeline network, post biogas scrubbing, compression and injection into the pipeline network. The LCA grave includes end-of-life activities.

Users of biomethane require full cradle to grave emissions assessment.

Cradle to gate emissions satisfies user emissions reporting GHG Protocol, Scope 3, Category 3 indirect emissions of the fuel and is often referred to as upstream well to tank / site emissions[2].

Cradle to grave emissions includes Transmission and Distribution (T&D) losses and the combustion of the biomethane. Combustion emissions satisfies user emissions reporting GHG Protocol, Scope 1, Category 1 direct emissions. T&D emissions satisfies user emissions reporting GHG Protocol, Scope 3, Category 3 indirect emissions.

The lifecycle stages within the cradle to grave system boundary include Feedstock production, feedstock transportation, fuel production, fuel distribution, and fuel combustion.

For each of these stages the activities (form GHG activity data) considered are:

I. Extraction of feedstock
II. Transportation of Feedstock
III. Production – Operational Energy including electricity and fuel use. (including grid and onsite generation)
IV. Production - Consumable materials (e.g. chemicals)
V. Production - Process emissions (including Fugitive emissions)
VI. Transportation processes downstream of plant – including T&D Loss

Considerations to setting the boundary may be repeatedly applied and include all processes which could have a material impact in the entirety of the development and operations process.[3] A significance screening should be done so that significant contributing sources to the carbon intensity are considered and processes which have a de minimis contribution and/or limits such as lack of data or high uncertainty can be excluded from the model. For biogas production the specific system characteristics informs the sources of emissions the system boundary.

[2] Corporate Value Chain (Scope 3) Accounting and Reporting Standard

[3] World Biogas Association, International Anaerobic Digestion Certification Scheme, Life Cycle Assessment, Standard Methodology Guidance, 2024

For landfill, emissions associated with the collection, transportation, and processing (e.g., size reduction, digestion) of the landfill gas, downstream transportation of the biogas, and end-use activities (if biogas is not upgraded for electricity and transportation fuel) are included.

For wastewater, emissions associated with the collection and purification of the produced biogas, downstream transportation of biogas, and end-use activities are included, and for food, emissions associated with the collection, transportation, and processing of food waste to biogas, downstream transportation of biogas and end products, as well as end-use activities are included.[1]

The System boundary for the Draft Bravetrace RNG REC certificates in New Zealand is a cradle to gate boundary approach which includes upstream emissions of extraction of feedstock materials and transport of feedstock, and production emissions from pre-processing, production, and storage, and the supply of gas to the distribution point.[4]

In the UK, certificates for green gas should include the upstream emissions for production and transport which is to be reported as part of a biomethane users scope 3 emissions within the ghg inventory.[5]

The World Biogas Association GHG methodology LCA boundary is cradle to gate which excludes end use combustion as depicted below:

[4] Bravetrace NZ / Certified Energy, Method for assessment and certification of renewable gas production, Version 1

[5] Green Gas Certification Scheme (GGCS) UK, Guidance Document 15, Use of Green Gas Certification Scheme within the GHG Protocol, 2022

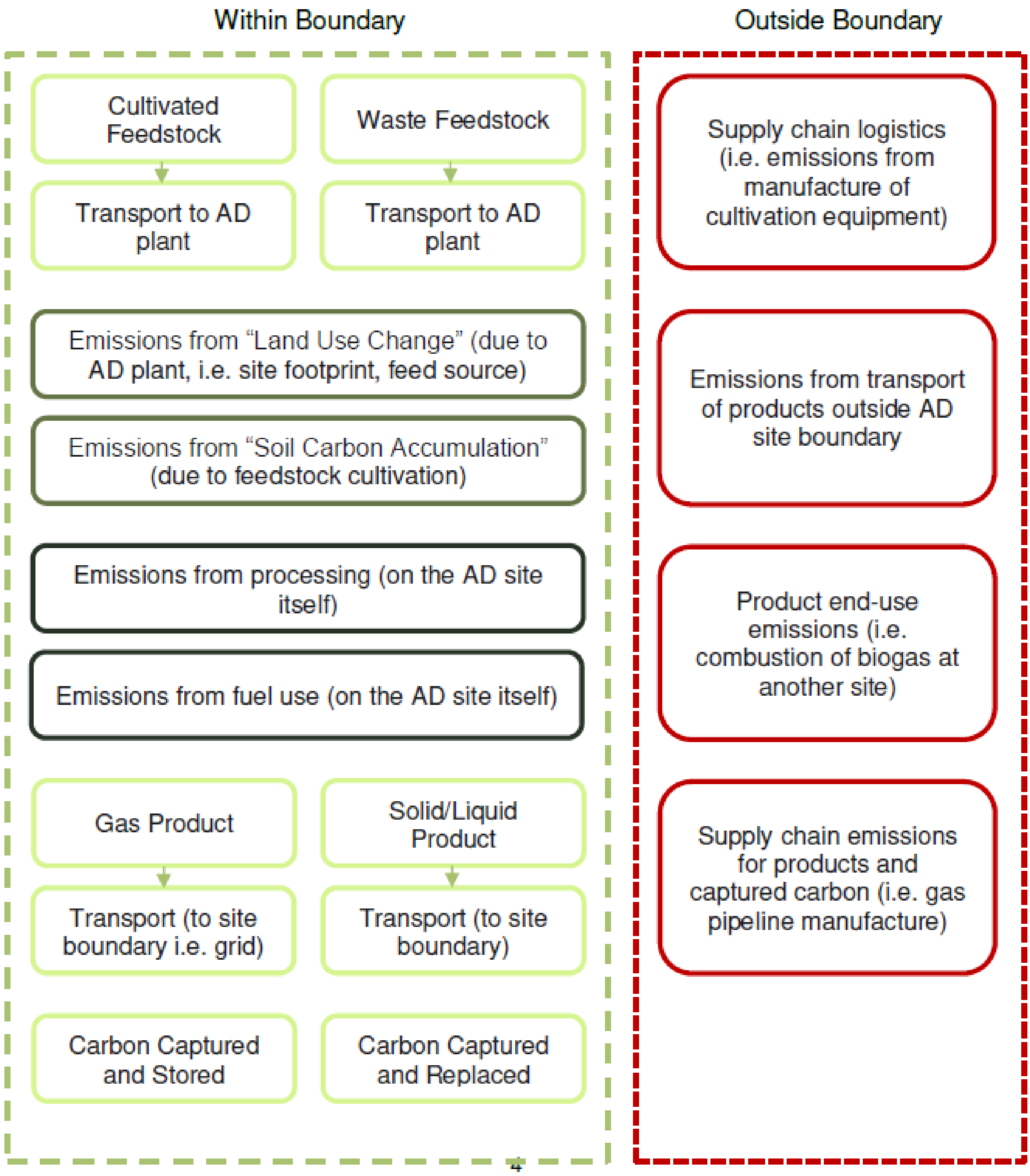

Figure 2 – System boundary American Biogas Association and World Biogas Association GHG methodology.

6.4 What are the temporal boundary requirements?

Temporal boundary requirements are commonly annual for Carbon Footprint LCAs based on ISO 14067-1. Annual biomethane carbon intensity reporting is required by all of the international REC schemes and Renewable fuel standards identified in the research including REDcert, Canadian CFR, and UK Green Gas Certification.

6.5 How is biogenic carbon accounted?

Biogenic carbon / GHG emissions are not included in the gross emissions and carbon intensity of a product carbon footprint. Biogenic emissions are estimated and separately reported from gross emissions in alignment with ISO 14067 Product Carbon Footprint Standard. [6]

In the context of GHG accounting, biogenic carbon is treated as being carbon-neutral due to it's provenance in the short-term carbon cycle which does not lead to a net increase in atmospheric CO_2 levels [7] as it is assumed to go back to the biosphere within 100 years. [8] Capture of biogenic CO_2 is a direct net carbon removal method, where one tonne of biogenic CO_2 captured by an AD plant is treated as one tonne of CO_2e emissions saved in its operations. [9] Combustion of LCIF (low carbon intensity fuel) is therefore set to 0 within carbon intensity models.

For crops, biogenic CO_2 emissions from land management practices may be considered as well as biogenic CO_2 and CH_4 emissions from land use change for hydro reservoirs. [10] Certification schemes require biogenic carbon to be reported separately from the rest of the GHG emissions which are reported as a single aggregate in CO_2e. [11] Direct emissions from other biogenic GHG's (CH_4 and N_2O) are still to be reported as part of Scope 1 emissions. [12]

7 Carbon intensity model features

7.1 What are the typical GHG sources within the Biogas processing plant?

The producer defines GHG sources and sinks from the inputs and outputs to their biomethane system.

Inputs and their associated emissions included in a model may be only considered when significantly contributing to the carbon intensity. Cut off criteria may include mass (material inputs), energy, and environmental significance which meet a defined 'material' percentage. Environmental significance is a useful analysis criterion to identify important inputs that may have been excluded by other criteria. Notable chemical inputs include enzymes, acids,

[6] ISO 14067-1

[7] International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE, World Biogas Association

[8] American Biogas Association; Carbon Accounting Methodology for Biogas

[9] International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE, World Biogas Association

[10] Environment and Climate Change Canada, Fuel life cycle assessment model methodology.

[11] Bravetrace NZ / Certified Energy Method for assessment and certification of renewable gas production, Version 1

[12] Green Gas Certification Scheme (GGCS) UK;

fertilisers, and catalysts. Additional Agricultural inputs such as pesticides and seeds may also be included.[13] There are often multiple outputs or "co-products" of the biogas process such as methane, digestate(biofertiliser), liquified CO_2, heat, electricity, and chemicals (e.g. ammonium sulphate fertiliser).[14] Methodology for renewable gas certificate in New Zealand have a defined materiality of <1% and the primary output being total gross CO2e of production emissions.[15]

7.1.1 Waste feedstock categorisation:

The key source of the biomethane product is the organic waste feedstock. Organic wastes from municipal solid waste (MSW) is typically characterised by percentage of degradable organic carbon (DOC) and the %dry or %total solids.

American Biogas Council Carbon Accounting methodology uses CA-GREET table below. If a waste cannot be categorised in any of the general waste categories, the following methodology can be used to estimate the DOC:

$$DOC = F_{DOC}\ X\ \frac{\%\ Volatile\ Solids}{100\%}\ X\ \frac{\%\ Total\ Solids}{100\%}\ (F_{DOC} x\ \%\ Vol\ Solids\ x\ Total\ Solids/100\%)$$

F_{DOC} is the fraction of the volatile residue that is degradable organic carbon (weight fraction); use the default value of 0.6. % Total Solids = 100% - % Moisture Content.

Default value of 0.6. % Total Solids = 100% - % Moisture Content.

A set of default DOCs for various types of waste is presented in Table 9.2.2,[16] where the data are adopted from the Greenhouse-Gas Emissions Estimation by RTI International. Project specific values may be used for each facility if available.

Table 1: Degradable Organic Carbon Values for Landfills

Landfill Waste Type	DOC (Weight Fraction, Wet Basis)
All Bulk Waste, Unseparated	0.2028
Bulk MSW	0.30
Construction and Demolition Waste	0.08
Diapers	0.24
Food Waste	0.15
Food Processing Industry Waste	0.22

[13] Environment and Climate Change Canada, Fuel life cycle assessment model methodology.
[14] International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE, World Biogas Association

[15] Bravetrace NZ / Certified Energy Method for assessment and certification of renewable gas production, Version 1

[16] https://www3.epa.gov/ttnchie1/efpac/ghg/GHG_Biogenic_Report_draft_Dec1410.pdf

Garden Waste	0.20
Inert Waste	0.0
Other Industrial Solid Waste	0.20
Paper Waste	0.40
Pulp and Paper Industry Waste	0.20
Sewage Sludge	0.05
Textile Waste	0.24
Wood and/or Straw Waste, Wood Products	0.43

7.1.2 Fugitive emissions:

Fugitive Emissions are the direct GHG emissions that escape during the RNG production process. Typical fugitive emission sources are,

1. fugitive emissions during scrubbing biogas and upgrading to biomethane,
2. digestate storage.

Direct emissions from the following sources should be considered as identified in the Canadian CFR specifications: The emissions from digester leakage, digestate storage and fugitive emissions must be taken into account in the CI of biogas produced in an anaerobic digester or biogas upgraded to RNG. An anaerobic digester will leak a portion of the produced biogas and these **digester leakage emissions** must be included in the calculation of the CI of biogas or RNG for production pathways that involve an anaerobic digester. **Fugitive methane** emissions occur in the process of upgrading biogas to RNG and must be taken into account in the RNG CI value calculations.

Table 33: Direct emissions to include by pathway

Pathway	Direct Emissions to Include
Biogas from landfill gas	Not Applicable
Biogas produced in an anaerobic digester from organic waste	Digester Leakage, Digestate Storage
RNG produced from upgrading biogas produced from landfill gas	Fugitive Emissions
RNG produced from upgrading biogas produced in an anaerobic digester from organic waste	Digester Leakage, Digestate Storage, Fugitive Emissions

Table 2: Table 33 from Canadian CFR standards

Default fugitive emissions rates within the Canadian CFR standard are[13]:

- 2% for landfills
- 2% for on-farm RNG plants
- 1% for off-farm RNG plants

7.1.3 Digestate storage and lagoons[17]

Digestate, the spent slurry from the AD tanks, can be used as a biofertiliser. The digestate will likely be stored in significant volumes preferably in a covered tank or lagoon. Depending on the AD process and treatment of the digestate, these liquids can still be biologically active and generate methane. This raises a few considerations to determine the GHG impact of digestate slurry management:

- Pasteurisation of digestate. Whilst enhancing the quality and biological safety of the slurry for human use, this can also reduce the rate of residual methane generation by effectively eliminating the active biology.
- Separation of digestate into solid/liquid fractions. Raw digestate can be 90% water and therefore unfeasible to transport over large distances. This water content can be reduced by mechanically separating the slurry (i.e. with screw-press, centrifuge) into a pile of wet solids and a thinner liquid fraction, which can be handled separately.
- Storage of slurry/solid/liquid in lagoons. In the UK and perhaps elsewhere, this is no longer considered good practice, and lagoons should now be covered to collect channel emissions. Otherwise, a rate of methane, CO_2 and nitrous oxide emissions may need to be measured or estimated from the open lagoon store.

7.1.4 Use of consumables:[17]

The AD process uses materials that need to be replenished at intervals for efficient operation. The following are examples of AD consumables:

- Activated carbon filter media, used for biogas cleaning
- Ferric hydroxide or ferric chloride chemical, used for hydrogen sulphide mitigation
- A range of engine/lubrication oils
- Chemicals for pH control i.e. sodium hydroxide or hydrochloric acid
- Chemicals for industrial cleaning i.e. sodium hydroxide “caustic”
- Trace nutrients for feeding the AD biology i.e. trace metals
- Water use, either in process or for wider site, and depending on location, may have an associated carbon impact.

7.1.5 Digestate Application to land:

Digestate Application: In a biogas system, digestate is often used as fertilizer. It contains nutrients and organic matter that can contribute to soil health and carbon content. When applied to the fields, digestate helps build up soil organic carbon (SOC), improving soil structure, fertility, and water retention. The solid fraction of digestate from the AD process can be used as feedstock for biochar production. This converts digestate into a stable carbon-rich material, further sequestering carbon and enhancing the nutrient retention of biochar. The GHG Protocol have draft guidance on accounting on land sector application of biogenic fertilisers and SOC. [18]

Digestate application emissions is typically excluded from the RNG CI based on the Energy allocation method used and treatment of digestate as a byproduct. The American Biogas

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[17] World Biogas Association International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE
[18] https://ghgprotocol.org/land-sector-and-removals-guidance

Association methodology provides best guidance when accounting for digestate as a co-product vs. a byproduct (See figure below).

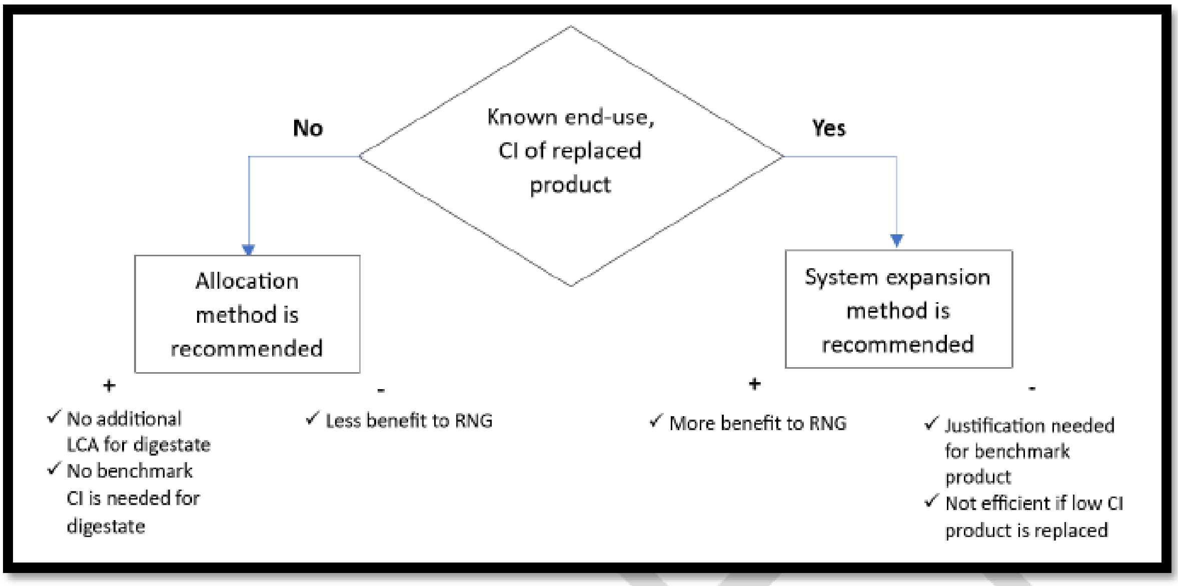

Figure 3 Digestate Allocation method

Digestate displacing synthetic fossil based fertiliser has associated avoided emissions calculations in the American biogas association methodology which can be calculated with the system expansion method. In system expansion, externalities (positive or negative) are considered and linked to the system, while they are not directly related to how a system operates or a product is made. The CI of benchmark fertilizer is subtracted from the overall anaerobic digestion process, leading to an improved CI for the biogas. The GREET models do not calculate avoided emissions for digestate application to land.

Figure B.1.3: Visual Demonstration of System Expansion Accounting Method in LCA

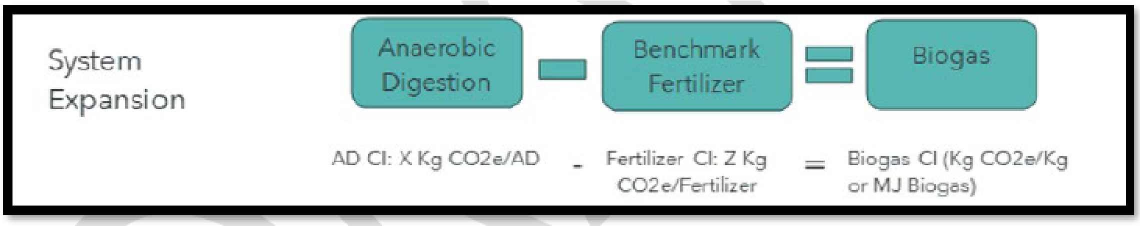

Figure 4 Digestate Avoided Emissions

7.2 How is embodied Carbon treated?

Embodied carbon is the GHG emissions associated with the materials, products, and equipment used to build an AD plant, including their extraction, processing, transportation, manufacturing, and end-of-life disposal.

Current REC schemes and Low Carbon Fuel Standards do not include embodied carbon from the construction of an AD plant or biomethane Project.

The World Biogas LCA methodology excludes the construction of the AD plant.[19]

The Canadian CFR LCA Model and methodology excludes the embodied carbon but acknowledges that more work is to be done to determine if this is acceptable.

The RED-II does not appear to consider the embodied carbon of construction and demolition of the AD plant itself.

Based on ISO 14067-1 Product Carbon Footprint standard, a full LCA would factor in the emissions generated from the production and organisation of materials used to build the AD plant (i.e. concrete digester tanks, buildings and foundations) as well as the emissions from demolition of the plant at the end of its useful lifetime (i.e. 20-30 years).

More work and Bioenergy NZ Steering group consideration is thus needed here, and it should be considered if this is a requirement determined by certification bodies.

7.3 What is mass balance?

Mass balance is an essential component of the EUs RED II Cert scheme which ensures that information about the sustainability of raw materials, intermediate and end products is credible in relation to its origin and type and can be verified along the entire production and supply chain.

The term "traceability chain" describes the chronological documentation of a process. It is a tool to track material through every step in the process. The mass balance system is a central element of the sustainability scheme. It establishes a connection between information or claims related to raw materials or intermediate and end products.

Mass balance refers to the principle that the mass entering a system must equal the mass leaving the system plus any accumulation within the system over a specified period. This is expressed mathematically as:

Mass In−Mass Out = Δ Storage

The primary goal of mass balance is to ensure that all material flows are accounted for, providing a check on the validity and completeness of the data. It helps in identifying discrepancies and ensuring that the system is accurately represented

ISO 14067 Product Carbon Footprint Standard, requires verification/ validation of mass balances and energy balances.

7.4 What are the internationally accepted formulas for CI?

Each international low carbon fuels programme and REC Schemes has their own calculation methodology, guidance, and models to support producers and the sector based on a Lifecycle Assessment (LCA) approach. Each methodology reviewed has similar LCA system boundaries but slightly different formulas, variables, default values.

[19] International Anaerobic Digestion Certification Scheme, Life Cycle Assessment, STANDARD METHODOLOGY GUIDANCE, World Biogas Association

Typically the formula refers to the country level emission factor database similar to NZs MFE emissions factors.

The list of formulas and calculators can be found Table 3.

Table 3: International RNG CI Schemes and Calculators

Jurisdiction	Scheme Name	Comments / Links	CI methodology / model	Avoided emissions
Europe	**European Energy Certificate System EECS** EECS | AIB	Renewable Energy Directive II (RED-II). **European Renewable Gas Registry (ERGaR) – tracking system**	REDcert standards. Logo REDCERT	Not addressed.
UK	**UK Green Gas Certification Scheme (GGCS)**	Does not verify emissions. Rely on Ofgem's sustainability reports. UK GGCS is a member of the ERGaR Certificate of Origin (CoO) Scheme. Emissions Reporting - Certificates - Green Gas Certification Scheme	Renewables Obligation: Sustainability Reporting | Ofgem	Not addressed.
Canada	**Canada's Clean Fuel Regulations (CFR)**	Canada's Clean Fuel Regulations (CFR) - Canadian Fuels Association	Methodology and Workbook must be used. Fuel Life Cycle Assessment Model - Canada.ca	Optional Reporting. Calculated separate to CI.
USA	American Biogas Association; Carbon Accounting Methodology for Biogas	CI methodology and Carbon Credits methodology	American biogas council	Covered
USA	**U.S. Renewable Fuel Standard (RFS)**	Renewable Fuel Standard Program | US EPA	US EPA GREET | Department of Energy GREET T1	Calculated. Calculated separate to CI.
California	**California's Low Carbon Fuel Standard (LCFS),**	Low Carbon Fuel Standard | California Air Resources Board	CA-GREET 3.0, CA-GREET 4.0 LCFS Life Cycle Analysis Models and Documentation | California Air Resources Board	Calculated. Calculated separate to CI.

7.4.1 GREET

The Greenhouse gases, regulated emissions, and energy use in technologies (GREET) model is a lifecycle analysis model based on supply chains of technologies and products, which is widely applied in the US. It is largely a process-based LCA approach (sometimes referred to as attributional LCA). GREET can be used to estimate the carbon intensity (CI) of individual supply chains. Fundamentally, GREET is most closely related to other supply chain LCA frameworks such as SimaPro, GaBi, and OpenLCA, though GREET differs in that it comes with predeveloped fuel pathways and prepopulated data and assumptions developed by ANL[20]. In general, GREET evaluates production of a fuel commodity by considering the activities from the associated supply chain

California Air Resources Board (CARB) in support of the California Low Carbon Fuels Standard (CA-LCFS), use their own localised version of the GREET Tool called the CA-GREET derivative. CA-GREET 4.0 is the latest of the carbon intensity Models found in the research published in Oct. 2024 it has just finalised public consultation.

7.4.2 EU Renewable Energy Directive II (RED-II)

In the EU, the RED-II methodology and calculation structure is typically followed. The RED-II methodology is also aligned to within the World Biogas Association RNG Methodology and the Canadian (CFR) Biofuel LCA Methodology and Model[21].

The RED-II calculation system is based on the following cradle to gate formula including combustion,

$$E = \sum_{1}^{n} S_n \times (e_{ec,n} + e_{td,\,feedstock,n} + e_{l,n} - e_{sca,n}) + e_p + e_{td,\,Produkt} + e_u - e_{ccs} - e_{ccr}$$

where:

E	greenhouse gas emissions from the production of biomethane before conversion into electricity
S_n	share of feedstock n, in fraction of input to the digester
$e_{ec,n}$	emissions from the extraction or cultivation of feedstock n
$e_{td,feedstock,n}$	emissions from transport of feedstock n to the digester
$e_{l,n}$	annualised emissions from carbon stock changes caused by landuse change, for feedstock n
e_{sca}	emission savings from improved agricultural management of feedstock n
e_p	emissions from processing
$e_{td,Product}$	emissions from transport and distribution of biogas and/or biomethane
e_u	emissions from the fuel in use, i.e. greenhouse gases emitted during combustion
e_{ccs}	emission savings from CO_2 capture and geological storage
e_{ccr}	emission savings from CO_2 capture and replacement

The RED-II formula includes calculation for land use change ($\mathbf{e_{l,n}}$) based on feedstock from energy crops. As the NZ methodology focuses on waste to energy, energy crops can be excluded.

The RED-II formula also includes avoided emissions from the savings from improved agricultural management of feedstock ($\mathbf{e_{sca}}$)due to improved agriculture practices to enhance soil carbon

[20] US EPA, Model Comparison Exercise Technical Document, June 2023
[21] Canadian Biofuel LCA Methodology

during feedstock production. As the NZ methodology is specific to biological waste this is not excluded.

Emissions savings from CO_2 capture and replacement acknowledge a similar principle to avoided emissions based on biogenic fuel use and combustion. "*Emission savings from CO_2 capture and replacement (**e_{ccr}**) shall be related directly to the production of biomass fuel they are attributed to, and shall be limited to emissions avoided through the capture of CO_2 of which the carbon originates from biomass and which is used to replace fossil-derived CO_2 in production of commercial products and services*."

Emission savings from CO_2 capture and replacement (**e_{ccr}**) is suggested to be excluded from the CI of the NZ RNG methodology as it is analogous to an avoided emission which is not part of an ISO 14074-1 compliant product carbon footprint.

Emission savings from CO_2 capture and geological storage (**e_{ccs}**) is suggested to be excluded from the CI of the NZ RNG methodology due to lack of available technology.

REDCert explains "Emissions from processing (ep) include emissions from the processing itself, from waste and leakage and from the production of chemicals or other products used for processing, including CO_2 emissions equivalent to the carbon content of fossil inputs regardless of whether they are actually combusted in the process. The following formula, which only applies for a single processing step, is used:"

$$e_p = \frac{EM_{electricity} + EM_{heat} + EM_{production\ inputs} + EM_{wastewater}}{yield_{main\ product\ dry}}$$

specified in mass units in relation to the dry matter content of the main product (gCO_2eq/t dry). (EM= emissions;[14] EF= emission factor)

$$EM_{electricity}\left[\frac{gCO_2eq}{a}\right] = \text{electricity consumption} \times EF_{electricity}$$

$$EM_{heat}\left[\frac{gCO_2eq}{a}\right] = \text{fuel consumption} \times EF_{fuel}$$

$$EM_{production\ inputs}\left[\frac{gCO_2eq}{a}\right] = amount_{production\ inputs} \times EF_{production\ inputs}$$

$$EM_{wastewater}\left[\frac{gCO_2eq}{a}\right] = amount_{wastewater} \times EF_{wastewater}$$

$$yield_{main\ product\ dry}\left[\frac{t_{dry}}{a}\right] = \text{annual dry yield of the main product}$$

Transportation is calculated as explained in below sections.

REDCert, has the aim of verifying that the production and supply of biomass or biofuels meet the sustainability requirements laid out in the Renewable Energy Directive II (RED-II). Currently, this is not considered to be a mechanism for generating carbon credits to be sold on a global market. Rather, this is a compliance method, to verify that bioenergy or biofuel production meets the sustainability criteria established by the Renewable Energy Directive II (RED-II) and can be a pre-requisite for producers and trades in the EU.

7.5 How are transportation emissions accounted for?

Transportation of feedstock is included in the RNG CI calculation for both the cradle to gate and the cradle to grave system boundaries of all the international methodologies assessed. This is considered an upstream emissions source.

Toitu have reviewed the international RNG GHG methodologies and calculators which all give option to use the standard fuel-based or distance-based methods of transportation emissions calculation as highlighted below.

Transportation emissions can be calculated in multiple ways as listed below in order of highest accuracy:

i. Fuel-based method: Litres of fuel consumed (by fuel type), for your specific share of the load
ii. Distance-Based method (Recommended): requires km or Tonne-km data, by freight mode (road, rail, sea, air) and vehicle type for all freight.
iii. Spend-Based method: requires spend data by freight mode.

REDCert calculates transportation emissions per below equation:

$$e_{td}\left[\frac{gCO_2eq}{t_{dry}}\right] = \frac{(d_{loaded} \times K_{loaded} + d_{empty} \times K_{empty}) \times EF_{fuel}}{m_{load\ dry}}$$

d_{loaded}	transport distance across which the biomass, biofuel, bioliquid or biomass fuel was transported [km]
d_{empty}	transport distance when the transport vehicle was empty (if the transport vehicle is not empty upon return, it does not have to be included) [km]
m_{load}	measured mass of the transported biomass, biofuel, bioliquid or biomass fuel [t dry]
EF_{fuel}	emission factor fuel [gCO_2eq/l]
K_{loaded}	fuel consumption of the means of transport used per km when loaded [l/km]
K_{empty}	fuel consumption of the transport vehicle used per km when empty [l/km]

Or below

$$e_{td}\left[\frac{gCO_2eq}{t_{dry}}\right] = \frac{(m_{\text{load dry in transport vehicle}} \times d_{\text{transported}}) \times EF_{\text{transport type}}}{m_{\text{load dry in transport vehicle}}}$$

Where:

$m_{\text{load dry in transport vehicle}}$	measured mass of the transported biomass, biofuel, bioliquid or biomass fuel that is transported in a specific transport vehicle [t dry]
$d_{\text{transported}}$	transport distance across which the biomass, biofuel, bioliquid or biomass fuel was transported [km]
$EF_{\text{transport type}}$	Emission factor of the specific transport type [$gCO_2eq\ t^{-1}\ km^{-1}$]

7.5.1 What default values and emissions factors?

Emissions Factor are typically provided within the RNG CI methodology calculators.

REDcert: For gas losses, an emission factor of 0.17 gCH4/MJ biomethane must be applied by the last interface.

Canada CFR defaults

CFR Specifications recommend that default fugitive emissions rate is a percentage of raw biogas flow as per below:

- 2% for landfills
- 2% for on-farm RNG plants
- 1% for off-farm RNG plants

Some other researched industry presentations suggests that digester leakage emissions should be 2% leakage factor (**~ 10 gCO_2e/MJ**) for enclosed vessel digesters and 5% leakage factor (**~ 25 gCO_2e/MJ**) for covered lagoons.

Defaults for feedstock degradable organic content (DOC) is shown in the above feedstock data requirements and is listed in the American Biogas Methodology.

Defaults for landfill cap oxidation (ABC methodology): The factor for the oxidation of methane by soil bacteria Equal to 0.10 for all landfills except those that incorporate a synthetic liner throughout the entire area of the final cover system where OX = 0

7.5.2 How are avoided emissions addressed?

Avoided emissions are defined as the “positive” impact on society when comparing the GHG impact of a solution to an alternative baseline reference scenario. example, livestock manure used to produce biogas or RNG can prevent CH_4 emissions from landfills, wastewater and BAU operations. Although the CI calculation for most of the schemes do not include avoided emissions, some methods such as the American Biogas Association Methodology and California Greet do have calculations to support avoided emissions assessment.

It is worth noting that avoided emissions can be significant and contribute to the sustainable business case for RNG. A 2021 research document created by Beca, Firstgas Group (now

Clarus), Fonterra and EECA outlines the potential of biomethane in NZ to generate avoided emissions. [22] "*The creation of valuable products like digestate and green CO_2 bolster the financial and environmental benefits of biomethane production and combined with the capture of biogenic emissions more than double the total emissions avoided throughout the product lifecycle*". The report claims avoided emissions of 19 times the carbon footprint of the biomethane across its lifecycle.

The World Bioenergy Association Carbon Intensity Methodology and the European Energy Certificate mandatory carbon intensity LCA methodology aligns with System (EECS) EU RED II methodology. These REC schemes and methodologies do not account for avoided emissions within their carbon intensity methodology.

The Canada Clean Fuel Regulations (CFR) LCA model and California's Low Carbon Fuel Standard (LCFS) CA-GREET model do calculate avoided emissions from upstream diversion of waste from a baseline to a project scenario. The reporting under these guidelines is optional however there is prescriptive guidance on calculations.

The California GREET (CA-GREET) model, part of California's Low Carbon Fuel Standard (LCFS), primarily focuses on assessing the life-cycle emissions of fuels, including Renewable Natural Gas (RNG). It does not require the reporting of Avoided emissions however allows for calculation of avoided emissions. A feedstock diversion credit for avoided emissions is calculated and applied to the Fuel pathway.

While the CA-GREET model indirectly considers the benefits of methane capture from RNG sources (such as dairies and landfills), the avoided emissions are built into the CI calculations rather than as a separate requirement. Some RNG industry stakeholders have suggested that avoided methane benefits could be more comprehensively counted, especially where organics diversion from landfills is involved, to better reflect RNG's full GHG mitigation potential.

The US Bioenergy Association methodology has the most prescriptive calculations and guidance on avoided emissions. Avoided emissions are assessed upstream (waste diversion) and downstream at the digestate application to land. These avoided emissions calculations are typically used for carbon credit projects or policy assessments.

NZ's Bravetrace Method for Renewable Gas Production (Version 1) requires the reporting of avoided emissions as a Net Emissions for the REC. Net Emissions with the Bravetrace methodology is defined as the cradle to gate LCA GHG emissions minus the avoided emissions. Avoided emissions assessment is required for repurposing of waste and generation of co-products. There are no details on how they should be assessed.

[22] Biogas and Biomethane in NZ - Unlocking New Zealand's Renewable Natural Gas Potential, 1/07/2021

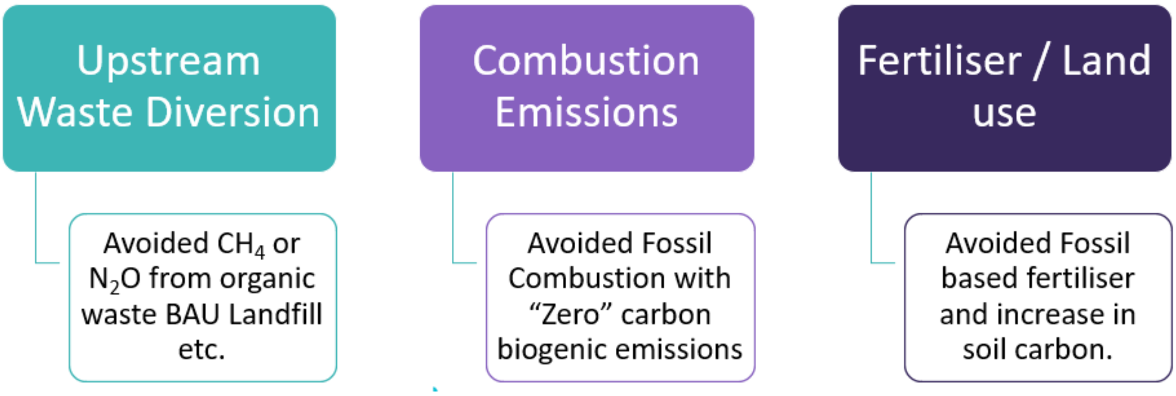

Figure 5 – Key areas in the biomethane lifecycle where Avoided Emissions can occur.

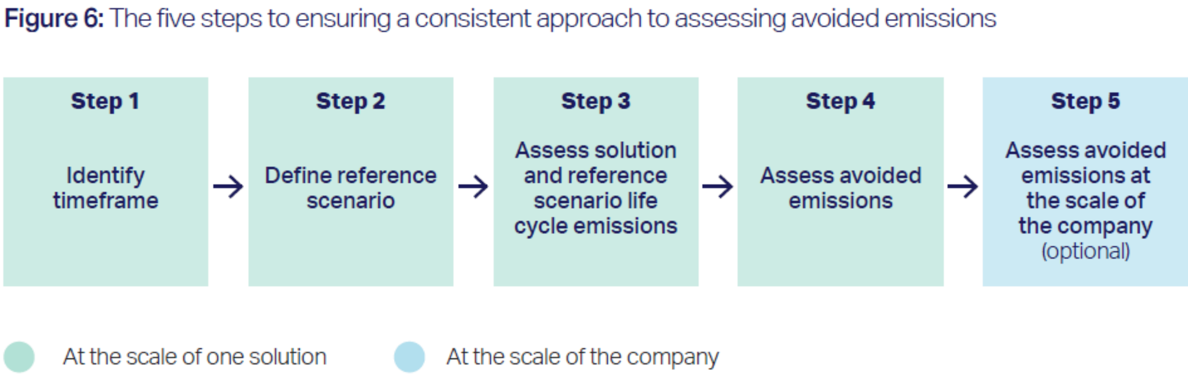

Figure 6 – WBCSD Guidance steps on assessing avoided emissions

RNG production avoided emissions are reductions beyond the footprint boundary based on ISO 14067, and to align with this standard along with the World Bioenergy Association, Californian, EEC and Canadian guidelines it is recommended that the NZ CI methodology excludes avoided emissions.

Avoided emissions are part of the net emissions impact of a project and are often quantified to enable carbon credits in methodologies from the UNFCC Clean Development Mechanism, Verra and Gold Standard. The Clean Development Mechanism (CDM) is a framework under the Kyoto Protocol that allows developed countries to meet part of their greenhouse gas (GHG) reduction commitments by investing in emission reduction projects in developing countries. These projects generate Reductions via carbon credits, which can be traded on international carbon markets. These carbon credit methodologies must undergo an integrity assessment from the ICVCM to ensure it meets latest best practice and can be used by voluntary carbon markets (VCM). Most recently the AMS iii G – Landfill Methane Recovery version 10, was approved by ICVCM [23] for the VCM.

Avoided emissions are excluded from the organisational reporting boundary of users of biomethane based on the requirements of ISO 14064-1. Avoided emissions are best accounted

[23] ICVCM announces first high-integrity CCP-labelled carbon credits

for using the ISO 14064-2 Project Accounting standard which looks at reductions of a project vs. BAU baseline emissions and is best suited for carbon credit projects.

Best practice guidance for quantifying and reporting beyond value chain mitigation is presented in the WBCSD Avoided Emissions Guidance[24].

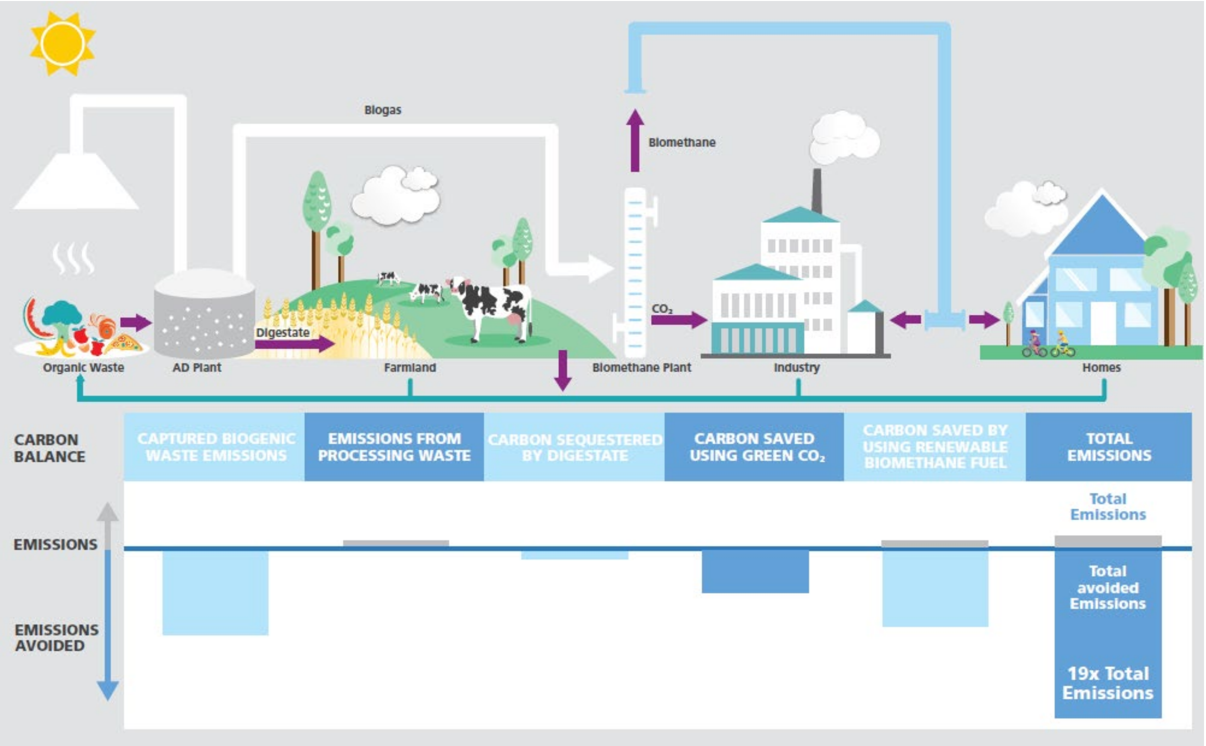

Figure 7: Avoided Emissions across the lifecycle of biomethane

7.5.3 What are the points on WWTP Carbon Intensity Calculation?

Sludge, the solids removed in wastewater treatment plants (WWTP) and organic matter produced during treatment, can be used as an input to AD processes for biogas production. Most WWTP with anaerobic digestion facilities use this resource in CHP plants for site based heat and energy requirements, but potential exists for the upgrading of biogas into RNG and production of co-products, for example a study by Watercare[25] supported by Mott Macdonald demonstrated potential for up to 15% of Auckland's residential gas supply to be produced at the Māngere WWTP.

Biogenic nitrous oxide (N_2O) occurs as the product of denitrification and/or nitrification of the nitrogen compounds found in wastewater by microorganisms, including as part of the treatment process itself. The major sources of biogenic methane and nitrous oxide in the wastewater network are illustrated in below figure4. Water NZ provide Accounting Guidelines for Wastewater Treatment which can be used as an input into the biomethane LCA methodology.

[24] WBCSD, March 2023: Guidance on Avoided Emissions: Helping business drive innovations and scale solutions towards Net Zero

[25] https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=6312

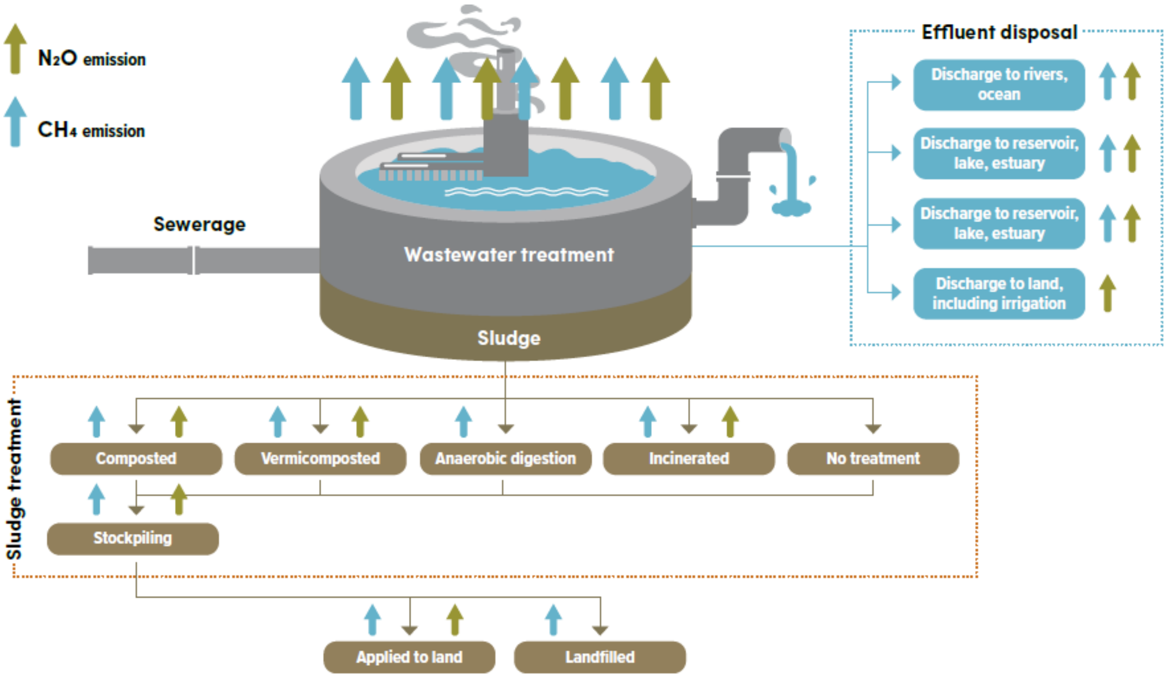

Figure 8 – Navigating to Net Zero, Water NZ, Wastewater emissions.

Generic processes of biogenic and non-biogenic waste may be used to model waste materials other than feedstocks that already have a defined process. Solid waste management and wastewater treatment process could be excluded from databases due to limitations such as lack of data, high uncertainty, or de minimis contribution. [26] Baseline WWTP that may be affected by project activity include: GHG emissions produced by electricity or fossil fuels, fugitive methane emissions from baseline wastewater treatment systems, and fugitive emissions from baseline sludge treatment systems.

Project emissions may include CO_2 emissions from electricity and fossil fuels used by the project facilities and fugitive methane emissions from sludge treatment system. [27]

[26] Environment and Climate Change Canada, Fuel life cycle assessment model methodology.
[27] American Biogas Association; Carbon Accounting Methodology for Biogas

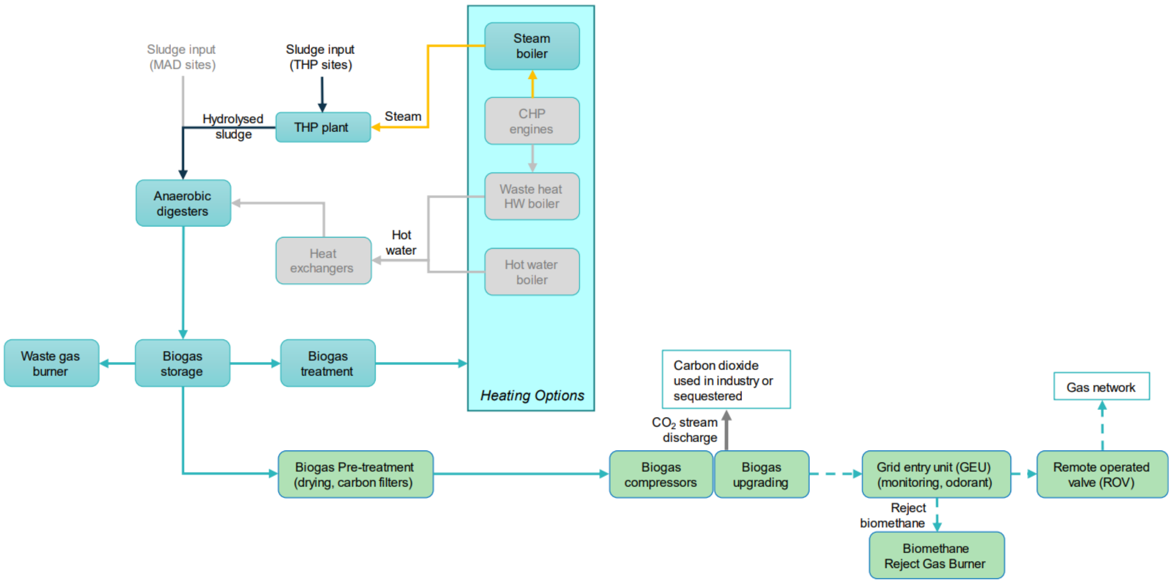

Figure 9 Biogas in Wastewater Treatment [28]

The system boundary and key source inclusions and exclusions into the WWTP carbon intensity model is shown below from the American Biogas Association GHG methodology:

Figure 7.2.1: General System Boundary for Wastewater Sludge Digestion Baseline and Project Scenarios

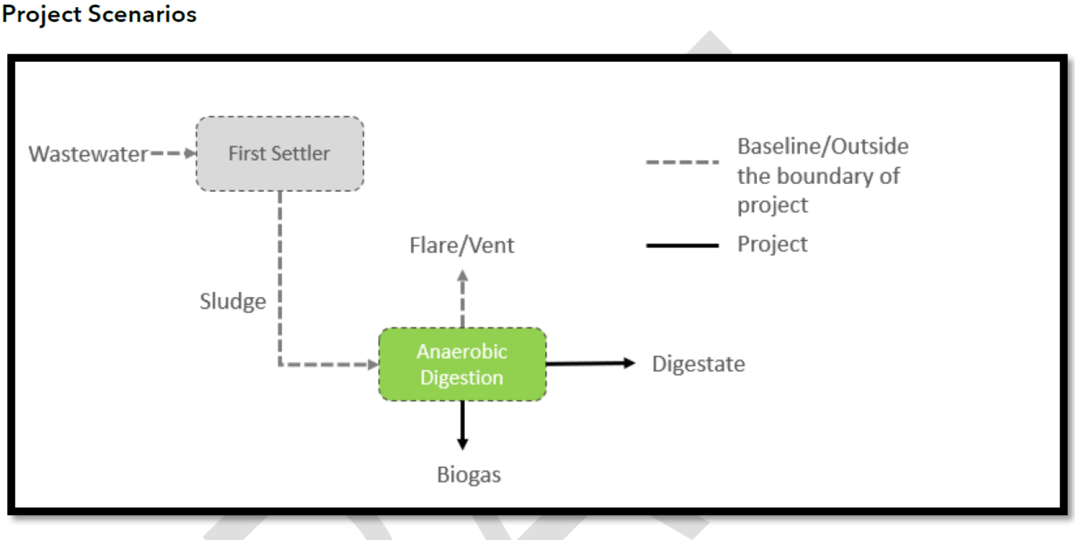

Figure 10: Figure 7.2.1 of American Biogas Association Carbon Accounting Methodology for Biogas **WWTP AD Treatment of Sludge.**

Table 4 GHG SSRs Included or Excluded from the Wastewater Project Boundary

[28] THE FUTURE OF BIOGAS IN WASTEWATER TREATMENT, 2023, David Hume (Mott MacDonald), Chris Thurston (Watercare Services Ltd.), James Newton (Mott MacDonald), Michael Whittome (Mott MacDonald)

SSR	Emission Source	Gas	Baseline (B), Project (P)	Included/Excluded	Justification
Feedstock Production	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Excluded	Wastewater treatment is assumed to be sourced from the same location in the baseline and project.
Feedstock Collection	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Excluded	Emissions related to the collection of the feedstock are assumed to be similar from baseline to project.
Feedstock Transportation	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Excluded	Wastewater treatment is assumed to be sourced from the same location in the baseline and project.
Feedstock Treatment	Electricity consumption	CO_2, CH_4, N_2O	B, P	Included	The change in the treatment process is included from the baseline to the project.
Feedstock Treatment	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Included	The change in the treatment process is included from the baseline to the project.
Product Related – Transportation of Final Product	Electricity consumption, fugitive loss	CO_2, CH_4, N_20	P	Included	The emissions related to the transportation and injection of the upgraded RNG in the project.

7.5.4 What are the key points on LFG Carbon Intensity Calculation?

Landfill Gas (LFG) is created from the anaerobic digestion of organic waste within landfills.

In New Zealand, large municipal landfills over 100Te (class 1) are required to have landfill gas capture systems installed where feasible. These systems are required to meet the National Environmental Standards for Air Quality (monitored by the EPA) and are defined by MFE and Resource Management Act (RMA). **Class 1 landfills in New Zealand must implement a landfill gas management system designed to capture and control emissions, helping to mitigate greenhouse gas release and manage odour.**

Landfill gas control systems include:

- **Collection**: Gas collection wells are positioned throughout the landfill based on the volume, density, depth, and area of the landfill.
- **Conveyance**: The gas is conveyed to a treatment system via a localised pipe network.
- **Treatment**: The gas is typically flared or further treated for use.

Landfill Gas Technical Guidelines can be found here: Technical Guidelines for the Disposal to Land - Project Team Draft - Revised B, MfE comments

The American Biogas Association provides the most prescriptive analysis of LFG to biomethane project accounting. A baseline scenario for a landfill includes collecting biogas which is flared and not upgraded, with the assumption that modern day landfills have gas collections systems in place. Baseline emissions are quantified through the degradation of waste in the area, the depth of the landfill, and gas composition and flow rate of ground emissions.

Biogas project emissions would include all direct and indirect emissions such as direct emissions from activities and indirect emission from consumption of energy (electricity, natural gas) and materials.[29]

In Figure 10 below you can see the baseline /business as usual (BAU) relative to the LFG to biomethane project. The dotted lines show the BAU waste treatment process with the solid line showing the biomethane project upstream boundary. There is also a table within the methodology showing the inclusions and exclusions of sources for LFG projects.

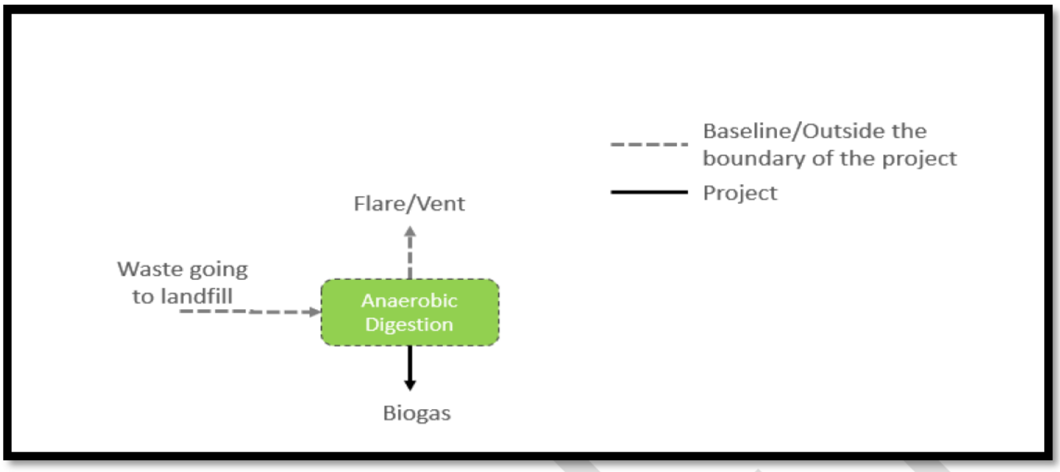

Figure 11: Figure 6.2.1 below American Biogas Association Carbon Accounting Methodology for Biogas

7.5.5 methodology steps to organic waste AD Carbon?

Within NZ and globally there is a significant effort to divert organic waste from going to landfills so that it can be used for other beneficial uses such as composting and bioenergy. Most recently this is observed by the Ecogas / Pioneer Energy, Reporoa AD plant which accepts Auckland Council, Tāmaki Makaurau residential food scraps to create renewable energy and fertiliser.

The food/ organic waste AD RNG system diverts organic waste from landfills so that it can be used for bioenergy. Food / organic waste baseline emissions are the most likely business as usual alternative treatment of the organic waste. The food / organic waste project emissions are the actual GHG emissions that occur within the LCA boundary after the installation of the biogas control system (BCS) due to the energy demands of the project equipment. Project emissions are calculated on an annual, ex-post basis.

A baseline scenario for Food may be where food waste is not collected for digestion and biogas production.

[29] American Biogas Association; Carbon Accounting Methodology for Biogas

For an anaerobic digestion plant, emissions calculated would include all emissions from associated activities and processes. Direct emissions include emissions from activities such as food waste collection, handling, and treatments before anaerobic digestion. Indirect emissions include those from consumption of energy (e.g. electricity, natural gas) and materials such as chemicals used in the process. The emissions therefore may be calculated using a formula such as $PEi = PECO2, i + (GWPCH4 * PECH4,i)+ (GWPN2O * PEN2O,i)$ where PEi: Project emissions for the reporting period, MT CO_2e/year. [30]

Figure 11 illustrates the various alternative organic waste treatment process that represent baseline /business as usual (BAU) relative to the Anaerobic Digestion process. The dotted lines show the BAU waste treatment process with the solid line showing the AD project.

Figure 8.2.1: General System Boundary for Food Waste Digestion Baseline and Project Scenarios

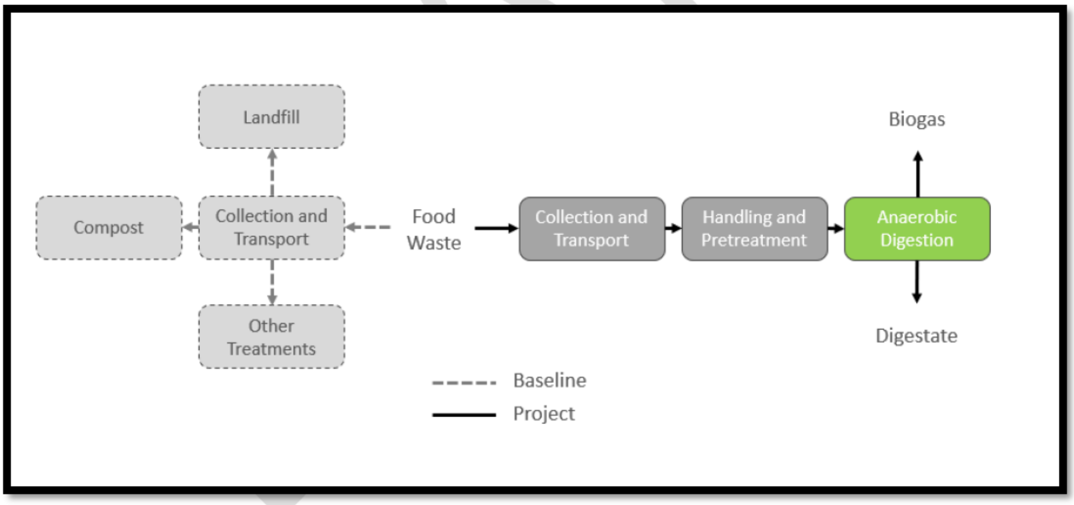

Figure 12: American Biogas Association Carbon Accounting Methodology for biogas (source figure 8.2.1)

7.5.6 How are emissions allocated across the co-products?

There are a few different allocation approaches. According to ISO 14044, the allocation approach should be avoided by further sub-dividing the system to isolate co-products, or by using the system boundary expansion approach. If allocation cannot be avoided, an allocation method based on physical causality (e.g. mass or energy content) or other relationships (e.g. economic value) should be used. [31] The Mass-based method allocates emissions based on the mass of each co-product. The economic method allocates emissions based on the market value of each product, where a product generating greater revenue takes on a greater share of the emissions [32]. For Energy-based allocation, emissions are divided based on the energy content of each co-product. The World Biogas Association Methodology suggests that the energy-based allocation is the most appropriate where the main product is used as an energy source. The Canadian Clean Fuel Regulations (CFR) Fuel life cycle assessment model methodology apply a default Energy Allocation approach also. The Canadian CFR LCA states "RNG and

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[30] American Biogas Association; Carbon Accounting Methodology for Biogas
[31] Environment and Climate Change Canada, Fuel life cycle assessment model methodology.
[32] International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE, World Biogas Association

biogas production does not produce any co-products that must be accounted for in the CI value calculations." [33]

REDcert is a globally leading RNG REC scheme in the EU Renewable Energy Directive. This certification system, recognized by the European Union, ensures that biomethane production or its use as fuel or electricity is sustainable according to EU requirements. REDcert states "*If other products ("co-products") are produced during a fuel production process in addition to the fuel, the total greenhouse gas emissions from the process are allocated between the biofuel, liquid biofuel and biomass fuel or intermediate product and the co-products according to their energy content (lower heating value)*." (Sect. 4.10, pg. 43.)

Based on the research it is recommend that this methodology applies an energy based allocation to the biomethane product based on the assumption that this is the only energy related product in the system and is the key focus of the intended users of this methodology. In this scenario, digestate production and CO_2 gas production outputs of the AD process are considered byproducts vs. coproducts. Byproducts are incidental and have less economic value relative to the main product whereas coproducts are intentional and create value alongside the main product. In the energy allocation method, all the carbon impacts of the byproducts such as Digestate and CO_2 are applied to the biomethane.

The advantage of energy based allocation for New Zealand is that it focuses the economic value and environmental impact on the RNG product which holds the majority of the economic and decarbonisation value.

7.6 How is the onsite electricity and heat generation addressed?

lectricity generated on-site which is then consumed for a product should be included as life cycle data for the product only where no contractual instruments have been sold to a third party. [34] Emissions for onsite electricity generation include all life cycle emissions up to the point where it is ready to be transferred to the grid. A maximum displaced electricity carbon intensity may be calculated to prevent overestimation of emissions reductions from excess generation. Where electricity is produced the typical technology used is a cogeneration system. [35]

Biogas used for flaring and home heating is assumed to have no upgrading of the biogas and is directly combusted for heating. The methane content is assumed to be converted to CO2 before release to the atmosphere.

Electricity generation with biogas is done through combustion of the biogas converted to mechanical energy through combustion technologies such as internal combustion engines and gas turbines. Electricity produced this way should be used onsite. Electricity emissions to be included in the system boundary are therefore: biogas transmission/transportation losses, combustion and mechanical conversion losses, and direct emissions from combustion of biogas (e.g., in boilers). [36]

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[33] Environment and Climate Change Canada, Fuel life cycle assessment model methodology. A2.5.3.4 Co-Products Produced

[34] ISO 14067-1

[35] Environment and Climate Change Canada, Fuel life cycle assessment model methodology.

[36] American Biogas Association; Carbon Accounting Methodology for Biogas

The Canadian CFR LCA methodology provides methodologies to calculate the CI of the electricity and thermal energy produced by the CHP system per section A4.2 and formula below:

3. Determine total quantity of thermal energy produced from the CHP during the calculation period ($Q_{Thermal}$) (MWh)
    - Applicant should provide the detailed methodology, including location and frequency of measurement, equations and enthalpy table.
4. $CI_{Thermal}$ is the CI of the thermal energy produced by the CHP system (gCO_2e/MJ). Refer to the CI for Purchased or transferred Steam/Heat in
5. Table 15 of this document. It is assumed that the thermal energy is produced from natural gas with 80% efficiency.
6. Determine the CI of electricity by using Equation 16 below.

Equation 16: Expression to be used to determine the CI of electricity.

$$CI_{Electricity}\left(\frac{gCO2e}{MJ}\right) = \frac{Emissions_{Total}\ (t\ CO2e) \times 1\ 000\ 000\ (\frac{g}{tonne}) - CI_{Thermal}\left(\frac{gCO2e}{MJ}\right) \times Q_{Thermal}\ (MWh) \times 3600(\frac{MJ}{MWh})}{Q_{Electricity}\ (MWh) \times 3600(\frac{MJ}{MWh})}$$

$$CI_{Thermal} = 84\ gCO2e/MJ$$

Electricity can also be exported into a local grid and due to displacement of fossil energy, may gain credits depending on the original grids carbon intensity, though generally most AD facilities will just consume heat and energy themselves and not generate credits. If a cogeneration system is not included, electricity may be imported from a local grid.[37]

Based on ISO14067-1, contractual instruments can include energy attribute certificates, renewable energy certificates (RECs), guarantee of origin (GOs) or green energy certificates.

Emissions factors for electricity grid shall be NZ specific (MFE) and aligned with the closest temporal period for which the annual LCA assessment is completed. Electricity EFs should be applied on a quarterly basis as a to acknowledge the seasonal fluctuations in the grid as well as in the temporal accuracy of biomethane production.

7.7 What are the verification / assurance requirements?

Verification is the process of evaluating an environmental claim with past historical data to determine whether it is materially correct and conforms to predetermined criteria38.

There are two levels of assurance which can be completed by an independent assurance practitioner to convey the degree of confidence in the LCA and carbon intensity Claim being made by the producer:

[37] International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE, World Biogas Association

[38] Verification is ISO language and is not used by financial auditors. [Source: Adapted ISO 14064-3]

3**Limited assurance:** level of assurance where the nature and extent of the verification activities have been designed to provide a reduced level of assurance on historical data and information.

Reasonable assurance: level of assurance where the nature and extent of the verification activities have been designed to provide a high but not absolute level of assurance on historical data and information.

The biomethane LCA and carbon intensity verification should be completed to a limited level of assurance (at a minimum) on an annual basis, against this methodology which aligns with to ISO 14064-3 and ISO 14067-1.

American Biogas Accounting Methodology requires annual verification of the carbon intensity LCA. To validate and verify any of the projects using the current methodology, the validation and verification body (VVB) must have a valid accreditation under ISO 14065:2020 (general principles and requirements for bodies validating) and verifying environmental information certified by ANSI National Accreditation Board (ANAB) under the sectorial scope defined as Waste Handling and Disposal.

California Low Carbon Fuel Standard states 3rd party verification of the fuel pathway is required to obtain CARB certification. Annual verification of CI and transaction report is required to maintain certification .

I-REC scheme states evidence of the output of a production facility for a specified production period must be gathered and validated by an independent production auditor. The issuer may accept alternative validation when local legislation designated both the production facility and the production auditor as one and the same. A registry shall document and provide to the foundation for review the method of associated algorithms used for validation of any data or input. Accreditation is generally arranged by the foundation but may also be organized with third-party support or input, subject to the approval by the board.

World Biogas Association GHG methodology is silent on assurance and verification.

In Europe the European Energy Certificate System (EECS) uses the RED II Standards for accounting for biomethane GHG emissions. The RED II standard requires all data measured and collected on site which is relevant for the calculation of actual values must be documented and provided to the auditor for verification. RED II requires an Audit Report with the carbon intensity calculation to be completed annually.

NZs Bravetrace biomethane REC V1 standard suggests that Certified Energy do a review of the CI LCA report. There is limited detail on the requirement and standards of the verification body and verification standards.

ISO 14067-1 Product Carbon Footprint Standard requires the verification body to be accredited under ISO 14065:2020 with a verification in alignment with ISO 14064-3. ISO 14064-3 details requirements for verifying GHG statements related to GHG inventories, GHG projects, and carbon footprints of products. It describes the process for validation or verification, including validation or verification planning, assessment procedures, and the evaluation of organizational, project and product GHG statements.

14064-3 nominates 14066 which specifies competence requirements for validation teams and verification teams. It includes principles and specifies competence requirements based on the tasks that validation teams or verification teams must be able to perform.

ISO 14065 defines requirements for bodies that validate and verify GHG statements. Its requirements cover impartiality, competence, communication, validation and verification processes, appeals, complaints, and the management system of validation and verification bodies. It can be used as a basis for accreditation and other forms of recognition in relation to the impartiality, competence, and consistency of validation and verification bodies.

UK GGCS requires annual assurance to 31000 – general sustainability reporting.

The Canadian CFR is most prescriptive on assurance requirements within the Canada Clean Fuel Assurance Standard. The Team must verify to ISO 14064-3 but also meet the below requirements:

In accordance with ISO 14066, the verification team, excluding specialists, collectively demonstrates that they have the necessary skills and competencies to undertake a verification.

Verification teams demonstrate that they:

1. *Understand the requirements of the CFR, including:*
- *Fuels regulated (fossil), low carbon intensity fuels and creating compliance credits;*
- *The baselines chosen;*
- *The reduction requirements, if applicable;*
- *Scopes of the lifecycle;*
- *The regulatory criteria;*
- *Assurance level required; and*
- *Mandatory reporting requirements.*

2. *Understand greenhouse gas science, including:*
- *The processes that emit, remove or store GHG including technical issues associated with their quantification (e.g., emission factors, emission inventories, production, etc.), monitoring, and reporting;*
- *The applicability and limits of the prescribed quantification methodologies;*
- *The types of GHG sources and sinks associated with fuel lifecycle; and*
- ***The Specifications for Fuel LCA Model CI Calculations. (i.e. NZ RNG CI Methodology)***

3. *Understand the verification process as described in ISO 14064-3*

4. *Understand life cycle assessments, including:*
- *The concept of functional units;*
- *The fuel system boundaries;*
- *Any allocation procedures; and*
- *The assumptions, limitations, data quality and uncertainty used in the lifecycle.*

5. *Have understanding of the applicable sector(s) to which they are accredited described in Table 2, including an understanding of:*
- *The GHG sources, sinks, and reservoirs, common to the fuel lifecycle;*
- *The operational processes and production; and*
- *The uncertainty in the measurements and how this affects the assertions.*

6. *Have understanding in Computer Assisted Audit Tools and Techniques (CAATTs), for the verification of automated data management systems, when applicable, including:*
- *Have knowledge of the principles and rules guiding computer-assisted audits: An understanding of the Information Technology (IT) environment, and the core applications and relevant database structure;*
- *Have understanding and experience of examining highly automated data management systems using CAATTs.*

7. *Have a team member who speaks the applicable local language(s) fluently.*

8. *Have the following formal training:*
- *ISO 14064-3:2019 training;*
- *CFR4 verifier's basics course; and*
- *CFR verification recurrence course (every two years).*
- *The experience and the training completion of each member of the verification team is documented.*

UK GGCS REC Scheme also includes some specified assurance requirements, shown here.

Assurance approach

5.35. ISAE 3000 (revised) defines two types of non-financial data assurance engagement, a "reasonable assurance engagement" and a "limited assurance engagement". These refer to the level of acceptable assurance engagement risk and will determine how the verifier's conclusion is expressed.

5.36. In a reasonable assurance engagement, verification risk is reduced to a level where the auditor's conclusion is expressed positively. For example: "In our opinion, the operator has reported correctly for their biomass fuels, in all material respects, against the RO sustainability criteria." 5.37. In a limited assurance engagement, the risk is reduced to an acceptable level where the auditor's opinion is expressed negatively, eg: "Based on our work described in this report, nothing has come to our attention that causes us to believe that the operator has not reported correctly, in all material respects, against the RO sustainability criteria."

7.8 What are the data input quality requirements?

Based on ISO 14067-1, Primary data is quantified value of a process or an activity obtained from a direct measurement, or a calculation based on direct measurements. Secondary data is data which do not fulfil the requirements for primary data. Secondary data can include data obtained from proxy processes or estimates.

EUs REDcert GHG methodology states that to calculate the GHG emissions from biogas processing, the following data at a minimum must be collected on site, i.e. the respective values are taken from, e.g. company documents (ie. Primary Data):

Table 5 REDcert Primary Data:electricity consumption	total electricity consumption per year [kWh]

heat generation	type of fuel/combustible used to produce steam (e.g. heat-ing oil, gas, agricultural crop residues)
fuel consumption	total annual consumption of fuel for heat generation, (e.g. biogas and fossil gas (m3 or
production of inputs	quantity of chemicals or additional products (inputs) used in processing [kg a−1]
wastewater quantity	quantity of wastewater per year [l a−1]
yield main product	annual harvest of the main product [kg a−1]

American Biogas Association require the below to be measured and reported on site at the frequency in Table 6.

Table 6 Measurement frequency for Primary Data.

Parameter	Unit	Description	Frequency	Calculated (C), Measured (M), Reference (R)	records
PE_{CH4}	tCH_4	Methane emissions from the BCS (Biogas Control System) "System Device"	Monthly	M,C	
R	cal/Kmol	Ideal gas constant	Continuous, weekly, monthly, as required	R	
ELC_P	kWh	Electricity used in the project scenario	Monthly	M	Utility bills (each grid will need its utility bill)
F_{bg}	m^3/day	Biogas flow			
CH_4 content	percentage	Methane content of gas flow	Continuous, weekly, monthly, as required	M	Measure of raw biogas % before upgrading
FF_P	volume	Fossil fuels used in project scenario	Monthly	M	Utility bill
$PECH_4$, BCS	tCH_4	Methane emissions from the BCS	Monthly	M, C	
OX	0, 0.1	The factor for the oxidation of methane by soil bacteria	Uncertain	C	Equal to 0.10 for all landfills except those that incorporate a synthetic liner throughout the entire area of the final cover system where OX

					= 0
FFP	L / Volume	Fossil fuels used in project scenario	Monthly	M	Utility bill
FLFG	M^3	Landfill gas flow	Continuous (≤15 minutes)	M	
CH_4LFG	%	Landfill gas methane content	Continuous 1 (≤15 minutes)	M	

7.9 How would RNG REC certificates be treated in the user inventory?

If a company purchases biogas or biomethane through a contractual instrument that meets the GHG Protocol Scope 2 Quality Criteria, it can then report Scope 1 emissions for biomethane using the market-based method and using a specific (and often lower) emission factor[39].

1. Direct Scope 1 CO_2 emissions linked to the use of biomethane are zero
2. Direct emissions from other GHGs (CH_4 and N_2O) still need to be reported as part of a Scope 1 account.
3. Upstream emissions of green gas production and transport are reported as part of Scope 3 emissions and this data needs to be included on the certificate provided by the certification scheme.
4. Biogenic emissions need to be reported, but separately from the scopes in a memo item.

GHG Protocol Scope 2 Criteria requires some expert interpretation as it is currently written for renewable electricity certificates (REC). A significant part of biomethane demand needs to come from the voluntary market where the GHG Protocol guidance is an essential element as many companies rely on the protocol as main tool to account and report their GHG emissions. Currently, the GHG Protocol does not provide explicit guidance on how companies should use certificates to account for GHG emissions savings achieved by procuring biomethane. GHG Protocol has signaled more guidance in this area in their next update to the standard circa 2026.

7.10 How is Double Counting avoided?

Energy generated from all sources gets comingled and distributed through a shared network, making it necessary to have a verification method to substantiate claims to specific energy sources, including renewables. Ensuring that the same RNG is not sold and claimed for twice (or more) is known as avoiding double counting, and typically is managed by the framework and administration of REC schemes for RNG. REC schemes have tracking databases to administer the attributions of the RNG and the claims.

An energy attribute certificate (EAC) is a contractual instrument that conveys information (attributes) about a unit of energy, including the resource used to create the energy and the emissions associated with its production and use. EACs may also include information about the location of the facility that generated the unit of energy, when that facility began operations, and when the unit of energy was produced. EACs are an established tool for maintaining

[39] **GGCS Guidance Document 15, Use of Green Gas Certification Scheme within the GHG Protocol,** Version 1.5 – September 2022

transparency and clarity in energy sector transactions, as well as a mechanism for facilitating credible innovations that can increase the pace and scale of clean energy growth[40].

"EAC" is a generic term that includes all types of contractual instruments that convey rights to attributes from various types of energy (e.g., gas, electrical, thermal). Different countries may have different names for EACs.

A common type of EAC in is the renewable energy certificate (REC), used for electricity suppliers and consumers. RECs schemes are beginning to gain traction globally.

Double counting should not occur between different organisations Scope 1 and 2 emissions, however it may occur where the organisations direct Scope 1 and indirect Scope 2 emissions are another organisations indirect Scope 3 emissions.

An example of this is where biogas producing Company A generates emissions from the combustion of diesel in transportation and production of the product. This is categorised as Scope 1 for Company A. Company B purchases and uses the biomethane produced by Company A. Company B calculate their share of emissions associated with purchased/combusted biomethane from Company A, and account for Company A diesel transport and production emissions under Scope 3 (upstream emissions).

This type of double counting is accepted practice because

1. It optimises emission reduction opportunities and removals enhancements. Collaborative interventions are encouraged between the supplier (accounting for direct emissions) and the customers (accounting for indirect emissions).
2. It promotes organisational awareness of climate risks like cost of compliance, carbon pricing or emissions trading risks. By factoring these risks into the business, it encourages development of a decarbonised business model.

7.11 What are the fundamental requirements of a biomethane REC Scheme?

Certifications and Tracking are the two core elements of a RNG REC Scheme. The purpose of a RNG REC Scheme is to ensure a transparent and traceable link between production and consumption of RNG.

There are two types of certifications, **Guarantees of Origin (GOs**) and **Proof of Sustainability (PoS)**. Both types of certificates work together to enable a RNG market with slightly different purposes. Certificates are issued by approved certifying bodies.

By integrating GOs and PoS certifications into a comprehensive tracking system, the RNG REC system ensures that renewable energy is accurately accounted for, traded, and verified, supporting the development of a sustainable energy market.

PoS certificates require data on mass balancing and are designed to ensure sustainability of the feedstock and carbon intensity of the RNG and are typical for compliance markets.[42]

[40] Energy Attribute Certificates (EACs) | US EPA

GO certificates also called book and claim certificates are designed to disclose the RNG renewable energy share and title throughout the value chain. GO certificates are less rigorous and can be used for voluntary markets. The GO system operates on the "book and claim" principle, meaning that GO certificates can be traded separately from the physical gas and, therefore, can have a monetary value, notably in voluntary markets to disclose the renewable energy share of total energy use. The purpose of GOs is consumer disclosure showing the consumer a quantity of energy was produced from renewable sources.

In addition to the certification, tracking of the certified RNG is done via a national registry. National tracking systems (approved registries) issue and transfer GOs between producer, trader and end user**. The owners of the tracking system or contractual instrument registry should not also be active in the market for the same contractual instruments**[41].

Both the US and EU are leading the world stage on RNG REC Schemes. In the European Union, the trading of biomethane is legally tracked through **Guarantees of Origin (GOs)** and **Proof of Sustainability (PoS) certifications,** supporting biomethane capacity development and incentivising the use of sustainable low carbon feedstock. Additionally, the EU Database for Biofuels (UDB) will become operational at the end of 2024, facilitating the traceability of mass-balanced certificates.

Here's how the PoS and GO certificates work together and within the key stages of the REC scheme:

1. Issuance of Certificates:
- GOs: When RNG is produced, a Guarantee of Origin is issued to certify that the energy is from renewable sources. Each GO includes details such as the type of renewable source, production location, and the amount of energy produced[42].
- PoS: Proof of Sustainability certifications are issued to verify that the RNG production meets specific sustainability criteria, including environmental impact and greenhouse gas emissions reductions.
2. Tracking Systems:
- Both GOs and PoS certifications are tracked using electronic tracking systems. These systems assign unique identification numbers to each certificate, ensuring that each unit of RNG is accounted for and preventing double counting.
- Tracking systems maintain detailed records of each certificate, including its issuance, transfer, and retirement. This ensures transparency and traceability throughout the lifecycle of the RNG.
3. Transfer and Trading:
- Certificates can be traded between entities. For example, a producer can sell GOs and PoS-certified RNG to a utility or another buyer. The tracking system updates the ownership records accordingly.
- This trading mechanism supports the creation of a market for RNG, allowing producers to monetize their renewable energy and buyers to meet their sustainability goals.
4. Compliance and Verification:
- Regulatory bodies use these tracking systems to verify compliance with renewable energy standards and sustainability criteria. This helps ensure that the RNG being used or sold meets the required standards[42].

[41] GHG Protocol, Scope 2 Guidance, Scope 2 Guidance.pdf

- The tracking systems also facilitate the retirement of certificates once they have been used to claim renewable energy consumption, ensuring that each certificate is only used once.

Demand for REC Schemes:

“A significant part of biomethane demand needs to come from the voluntary market where the GHG Protocol guidance is an essential element as many companies rely on the protocol as main tool to account and report their GHG emissions. Currently, the GHG Protocol does not provide explicit guidance on how companies should use certificates to account for GHG emissions savings achieved by procuring biomethane.

Biomethane certification schemes have proved to be functional in helping to scale up biomethane production in the EU and US compliance-based markets. The report released today stated that additional clarity and alignment on the inclusion of biomethane in GHG Protocol, will facilitate the development of sustainable biomethane production and use globally.” [42]

“RNG certificate values are driven by a combination of different end-use market-specific factors; however, given the fungibility of RNG, most markets are inter-connected. **A key driver of RNG certificate values is feedstock carbon intensity (CI), which in some markets (e.g. US and EU road transport) can lead to a premium for RNG certificates over liquid biofuels • There is a strong need for consistent and rigorous tracking of biofuels, notably regarding specific properties, such as feedstock type and CI, which are increasingly important for GHG accounting requirements; as well as to provide market stability to support investment in new RNG production capacity •** Important changes lie ahead in the landscape of RNG tracking certificates. **In Europe, the EU Union Database for Biofuels (UDB) will be operational at the end of 2024, improving traceability of mass-balanced certificates.** In the US, demand from the non-transport sector is expected to take over as the driver for RNG demand growth, leading to new requirements for RNG certification
The importance of robust RNG tracking systems and understanding the value of RNG certificates become apparent when considering the expected unprecedented growth in RNG production to 2030. The EU has target to reach 35 Bcm/a (3.4 Bcf) RNG production by 2030 and US states and utilities are aiming for RNG targets of circa 6 Bcm/a (0.6 Bcf/d) for the non-transport sector, in addition to the current strong transport sector RNG demand. While these production ambitions represent multiples of current production, they represent only a fraction of the actual RNG production potential based on available sustainable feedstocks.”[42]

[42] Renewable gas tracking systems – Value of biomethane/RNG certificates, S&P Global for European Biogas Association, 2024

RNG certificates in Europe – Key differences

Guarantee of Origin (GO) and Proof of Sustainability (PoS) serve different purposes under the RED (EU/2018/2001)

Criteria	Guarantee of Origin (GO)	Proof of Sustainability (PoS)
Requirement	**Disclosure** of RNG renewable-energy share and title (ownership) tracking in accordance with RED requirements	**Compliance** with RED sustainability criteria
Sustainability	RNG must be produced from renewable sources	RNG must meet specific RED sustainability criteria
Issue	GO is issued by an official issuing body, e.g., national registry	PoS is issued by certified producers (who meet the requirements of a certification body which operates an EU approved certification scheme)
Transfers	RNG with GO is traded using the "book and claim" principle, allowing GO to be traded separately from physical RNG	RNG with PoS is traded using a mass balance approach, meaning that physical RNG and PoS should not be separated throughout the supply chain
Parties	GO is transferred to trader and/or gas supplier via national registry	PoS is transferred directly between certified RNG producers and gas suppliers.
Quotas and targets	RNG with GO only can not be used to fulfill obligations, quotas and targets set by EU legislation	RNG with PoS proves sustainability compliance and can be used to fulfill obligations, quotas and targets set by EU legislation

Table 7 : Key differences between the GO and PoS certificates

7.12What REC schemes have Carbon Intensity Thresholds?

Each of the RNG REC schemes studied specify a CI threshold, or other requirement such as lifecycle GHG emissions relative to baseline fossil-based alternatives. Below are reference to the CI thresholds found in research.

The US EPA sets specific GHG reduction thresholds for different types of renewable fuel to qualify under the RFS:

- **Conventional biofuels** must meet a 20% lifecycle GHG reduction relative to baseline petroleum emissions.
- **Advanced biofuels** and **biomass-based diesel** need to demonstrate a 50% reduction.
- **Cellulosic biofuels** must achieve a 60% reduction.

European Union RED II Directive mandates a minimum 70% greenhouse gas (GHG) reduction for biofuels, including RNG, used in transport compared to fossil fuels across the full lifecycle.

California's Low Carbon Fuel Standard (LCFS) requires RNG producers to demonstrate a CI that is lower than conventional natural gas, with dairy-derived RNG often qualifying as a negative CI fuel due to methane capture benefits. CARB assigns unique CI scores for each RNG pathway based on lifecycle analyses, making it among the strictest in minimizing the environmental impact of fuels.

Landfill gas-based RNG typically has a CI closer to 40–50 gCO_2e/MJ, while food waste and wastewater-derived RNG vary but are generally below 60 gCO_2e/MJ.

California Energy Commission California Air Resources Board

UK GGCS: The Regulations require that participants must produce renewable biomethane must have lifecycle greenhouse gas emissions of less than or equal **to 34.8 grams of carbon dioxide equivalent per megajoule of biomethane** (measured as the net calorific value) [43].

[43] Non Domestic RHI Sustainability Self Reporting Guidance (version 2), Ofgem, 23 May 2018

8 Appendix A References:

#	Source	Date /Yr	Link	Intended User	Intended Use
1	14067-1 Product Carbon Footprint.	2018	ISO 14067-1	Product Developer/ Biogas producer	Product footprint LCA
2	World Biogas Association ,International Anaerobic Digestion Certification Scheme, Life Cycle Assessment STANDARD METHODOLOGY GUIDANCE	2024	World Biogas Association	Producer	RNG Carbon Accounting
3	American Biogas Association; Carbon Accounting Methodology for Biogas	2024	ABC-Carbon-accounting-methodology-and-voluntary-markets-framework.pdf	Producer/ REC + Carbon Credits	RNG Carbon Accounting
4	Canada, Environment and Climate Change, Fuel life cycle assessment model methodology.	2024	Fuel life cycle assessment model methodology.	Product Developer/ Biogas producer	RNG LCA
5	Bravetrace NZ / Certified Energy Method for assessment and certification of renewable gas production Version 1	2022	Bravetrace	Biogas Producer	REC
6	Green Gas Certification Scheme (GGCS) UK;	2022	GGCS UK	Biogas Producer	REC
7	REDcert EU - Scheme principles for GHG calculation - Version EU 06	2023	REDcert EU Scheme documents	Biogas Producer	RNG LCA / REC
8	REDcert EU - Scheme principles for the production of biomass, biofuels,	2024	REDcert EU Scheme	Biogas Producer	RNG LCA / REC

	bioliquids and biomass fuels - Version EU 07		documents		
9	REDcert EU - Scheme principles for mass balance - Version EU 07	2023	REDcert EU Scheme documents	Biogas Producer	RNG LCA / REC
10.	Renewable gas tracking systems – Value of biomethane/RNG certificates, S&P Global for European Biogas Association, 2024	Oct, 2024	report on the trading of biomethane certificates | European Biogas Association	Biogas Producer	REC
11	International REC (I-REC)	2024	I REC	Biogas Producer	REC
12	GHG Protocol, Interim Update on Accounting for biomethane Certificates	2023	Accounting for Biomethane Certificates | GHG Protocol	Biogas User	Position Note
13	Canadian Biogas Association;	2024	Canadian Biogas Association	User and Producer	Various
14	EU Biogas Association	2024	European Biogas Association	User and Producer	Various
15	World Biogas Association	2024	https://www.worldbiogasassociation.org	User and Producer	Various
16	Australia GO	2024	Guarantee of Origin | Clean Energy Regulator	User and Producer	REC
17	Water NZ, Carbon accounting guidelines for wastewater treatment: CH4 and N2O August	2021	CarbonAccountingGuidelinesForWastewaterTreat	Municipal	Wastewater Treatment

			ment_1.1.pdf		
18	GHG Protocol FLAG emissions	2022 - DRAFT	https://ghgprotocol.org/land-sector-and-removals-guidance#supporting-documents	Farmer / Land owner	Digestate
19	GHG Protocol Scope 2 Guidance	2015	https://ghgprotocol.org/sites/default/files/2023-03/Scope%202%20Guidance.pdf	User and Producer	REC
20	Canadian Clean Fuel Regulations	2024	Compliance with the Clean Fuel Regulations - Canada.ca	User and Producer	Clean Fuel Standards